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HEAT AND TIME OF EXPOSURE NECESSARY TO KILL LARVÆ OF THE EUROPEAN CORN BORER IN EAR CORN[1]

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INTRODUCTION

Inquiries were received by the Bureau of Entomology as early as 1921 concerning the temperatures necessary to destroy larvæ of the European corn borer (*Pyrausta nubilalis* Hbn.) concealed in infested ears of corn. This information was needed especially by seed-corn growers who wished to ship seed on the cob from the area infested by the insect into uninfested territory, and by exhibitors at agricultural fairs, where the showing of ear corn was desirable.

It was soon found that the usual recommendations for destroying insects infesting stored products by heat would not apply to larvæ of the European corn borer. This is because these larvæ pass the winter in burrows throughout the corn plant, including the ears; and in the ears the insects are most frequently found in the center of the cob, which is a very poor conductor of heat. This renders necessary for their destruction a higher degree of heat, applied for a longer period, than would be needed for insects infesting the kernels only. The investigations of this subject were carried on during 1922, 1923, and 1924, and as a result of these it is possible to recommend an effective method for destroying larvæ contained in infested ears, so that the shipment of treated ears of corn from infested territory may be allowed without danger of causing new infestations of the insect.

THE HEATING APPARATUS

The heating chamber in which the tests outlined in this circular were made was a box the inside of which was 5 feet square and 4 feet

[2] The writer acknowledges his indebtedness to R. A. Vickery, W. O. Ellis, and L. B. Scott for assistance during the course of the experiments herein reported.

[1] This circular is a summary of a detailed report on the investigations which is on file in the Bureau of Entomology and is available for reference.

high. The walls consisted of three layers of ⅞-inch boards with building paper between the layers. The chamber was completely covered on the inside with asbestos which was laid on screening of ½-inch mesh, as is plaster. On one side was a close-fitting door about 3 feet square that could be held tightly shut by six clamps. This door was provided with a small glass window.

Heat was provided by four 500-watt, 110-volt, luminous radiator bulbs, two placed in opposite lower corners of the chamber and two in the alternating upper corners. Two of the heating bulbs were connected directly with the main electric circuit as auxiliary heating units to help raise the temperature of the chamber to the desired degree. The other two heating bulbs were thermostat-controlled to maintain an even temperature after the desired temperature had been obtained and the auxiliary heating bulbs had been turned off. A mercury thermostat consisting of a U tube 11½ inches long and 3 inches wide, constructed of tubing three-fourths of an inch in diameter, was used for the control of the temperature of the heating chamber.

DEGREE OF HEAT NECESSARY TO KILL FREE LARVÆ

In the study to determine the temperatures necessary to kill larvæ of the European corn borer contained in infested ears of corn, it seemed advisable at the outset, and preliminary to the actual heating of infested ears, to ascertain the temperatures necessary to kill larvæ when unprotected by the cob. Cages of cheesecloth glued on light wooden frames in the shape of 3-inch cubes were used for this purpose. One side of the cages could be opened to permit the introduction and removal of the larvæ. Hibernating larvæ were taken from cornstalks, put in the cage, and the cage placed in the heating chamber for the desired length of time, then removed, and the condition of the larvæ observed. Such cages were necessary because the larvæ become active on being warmed, and for accurate observation they must be confined. Larvæ contained in such cages were placed in the heating chamber and kept under constant temperatures of from 44° to 70° C. (111.2° to 158° F.) for periods of from 1 to 120 minutes. All larvæ were killed in 5 minutes at constant temperatures of 68° and 70° C. (154.4° and 158° F.), in 6 minutes at constant temperatures of 64° and 66° (147.2° and 150.8° F.), in 7 minutes at a constant temperature of 62° (143.6° F.), in 9 minutes at 60° (140° F.), in 11 minutes at 58° (136.4° F.), in 13 minutes at 56° (132.8° F.), and in 15 minutes at 54° C. (129.2° F.), whereas lower constant temperatures seemed to be ineffective in killing the larvæ.

Detailed studies were then made of the time necessary to kill larvæ at constant temperatures of from 58° to 66° C.—temperatures that seemed to be most effective in the previous experiments—and, that the work might be as accurate as possible, larvæ that had been previously kept at constant temperatures of approximately 12°, 10°, and 23° C. were brought to the heating chamber in different tests. The length of time necessary to kill free larvæ at the several constant temperatures was found to vary somewhat in the several trials, depending on the temperature conditions of the hibernating quarters from which the material had been obtained. Complete "kills"

were obtained at the following constant temperatures within the periods of time specified: At 66°, in from 4 to 6 minutes; at 65°, in from 4 to 6 minutes; at 64°, in from 4 to 7 minutes; at 63° in from 5 to 6 minutes; at 62°, in from 5 to 8 minutes; at 61°, in from 6 to 7 minutes; at 60°, in from 6 to 9 minutes; at 59°, in from 5 to 10 minutes; at 58°, in from 8 to 10 minutes. These experiments indicated that considerable variation in susceptibility to heat was characteristic of hibernating larvæ of this insect, some individuals being killed more readily by a certain degree of heat than others.

In each of these experiments, 10 larvæ were inclosed in the cheese-cloth cage during the test.

RISE OF TEMPERATURE WITHIN THE CENTER OF THE COB

Having ascertained the length of time necessary to heat free larvæ at several constant temperatures to obtain a complete "kill," the next step was to determine how long it would be necessary to heat ears of corn in order to bring the center of the cobs to the fatal temperature.

Special chemical thermometers[3] of about the thickness of an overwintering corn borer larva were obtained. These fitted into the insect's burrow in the cob (fig. 1) without unduly enlarging the hole and so interfered as little as possible with the natural protecting insulation of the cob.

Ears of corn with these thermometers inserted (fig. 2) were placed in the heating chamber at various constant temperatures, and readings were taken every five minutes. Figure 3 shows the rise of temperature within the ears of sweet, flint, dent, and pop corn at container temperatures of 40°, 50°, 60°, and 70° C., each curve being based on the averages of 10 tests. An examination of the curves shown in Figure 3 reveals the fact that although the temperature within the ears was raised considerably it was still below the constant temperature of the heating chamber after a 2-hour period. A continuation of the heating showed that usually more than five hours was necessary to bring the temperature of the center of the cob to the temperature of the heating chamber. The rise of temperature within the cob was quite rapid during the first hour of heating, much slower during the second hour, and thereafter was very slow indeed.

An examination of certain of the factors influencing the rise of temperature within the ear showed that the temperature within well-dried ears rose with considerably greater rapidity than did that within wet or moist ears. The kernels were found to be important insulating agencies, inasmuch as the temperature in the center of cobs from which the kernels had been removed was raised much more rapidly than the temperature in the center of cobs on which the kernels remained.

With a knowledge of the length of time necessary to heat free larvæ at various constant temperatures in order to produce a complete kill, and with information on the rapidity of the rise of temperature in the center of ears of corn of various types subjected to

[3] These thermometers may be described as follows: "Special engraved; range 0 degrees to 110 degrees C.; in 1-degree divisions; diameter, $\frac{1}{8}$ to $\frac{3}{16}$ inch; over-all length, 10 inches; scaled for 4½-inch immersion; nitrogen filled."

the same constant temperatures, a combination of these data should give a general idea of the length of time and the degree of tempera-

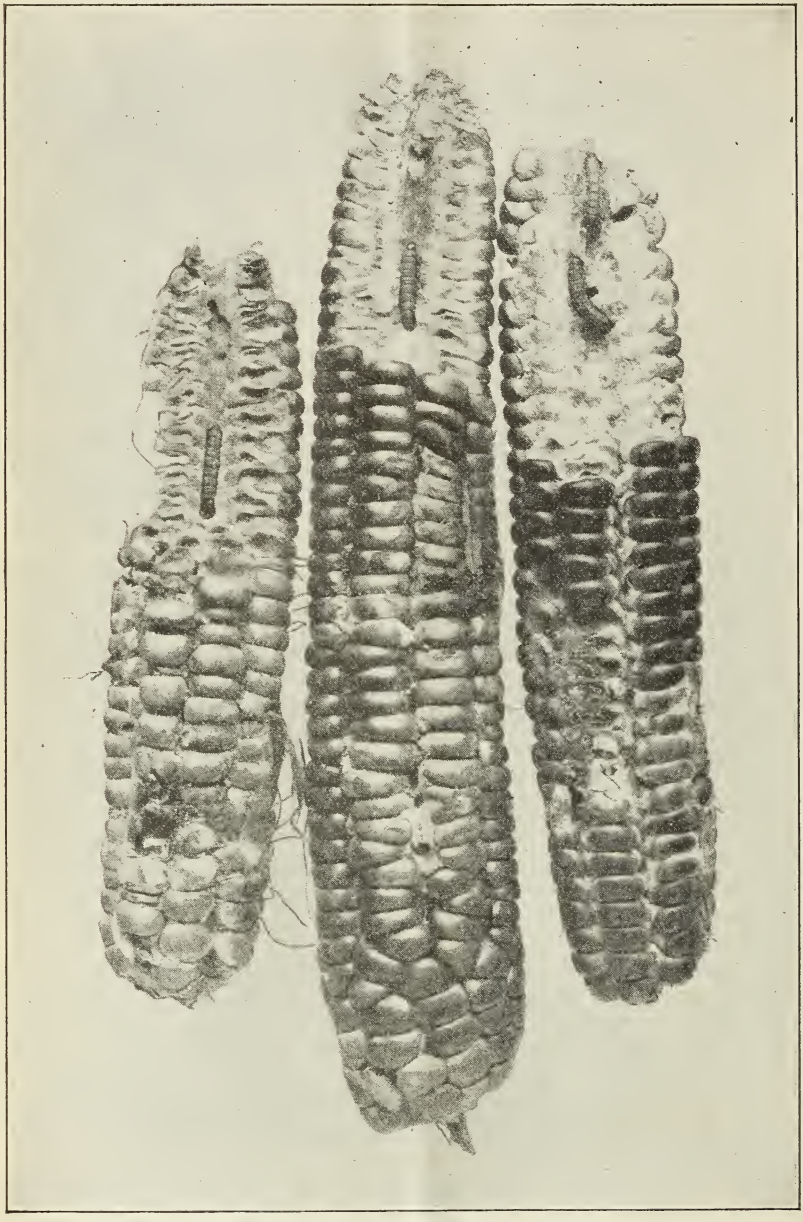

FIGURE 1.—Burrows of the European corn borer in the center of ears of corn

ture necessary to heat infested ears to insure a complete mortality of larvæ contained therein. It has been found that 15 minutes at a constant temperature of 54° C. was necessary to kill free larvæ, and

in Figure 3 it is shown that after a period of two hours of heating flint corn at a constant temperature of 60°, the temperature within the cob had attained 54°. It seems probable, therefore, that two hours of heating at 60° might not be entirely effective inasmuch as a certain proportion of larvæ might still be living at the end of the 2-hour period. Again, in Figure 3 it is shown that after a period of two hours' heating of flint corn at a constant temperature of 70° the temperature within the cob had attained a maximum of 62° plus, and had registered a temperature greater than 60° for about 35 minutes. In heating free larvæ it was found that a complete kill of free larvae was obtained in less than 10 minutes at a constant temperature of 60°, consequently at a constant temperature of 70° complete mortality of larvæ contained in flint corn might be expected in about one and one-half hours. In like manner comparisons may be made for each of four types; that is, sweet, flint, dent, and pop corn at several constant temperatures (fig. 3) with the degree of heat necessary to destroy free larvæ, and a general idea may thus be gained of the length of time necessary to heat infested ears so as to obtain complete destruction of the larvæ contained within them. These preliminary experiments were useful in restricting the actual heating of infested ears to temperatures and periods of time that were effective in killing the larvæ, and much preliminary work in actually heating infested ears was therefore unnecessary.

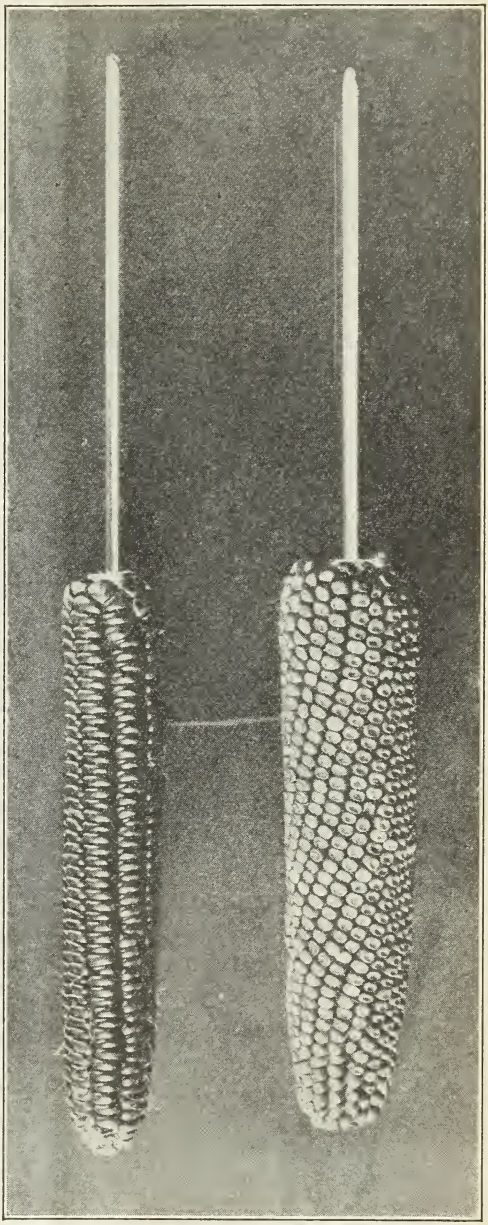

FIGURE 2.—Method of inserting thermometers to determine the rise of temperature within ears of corn

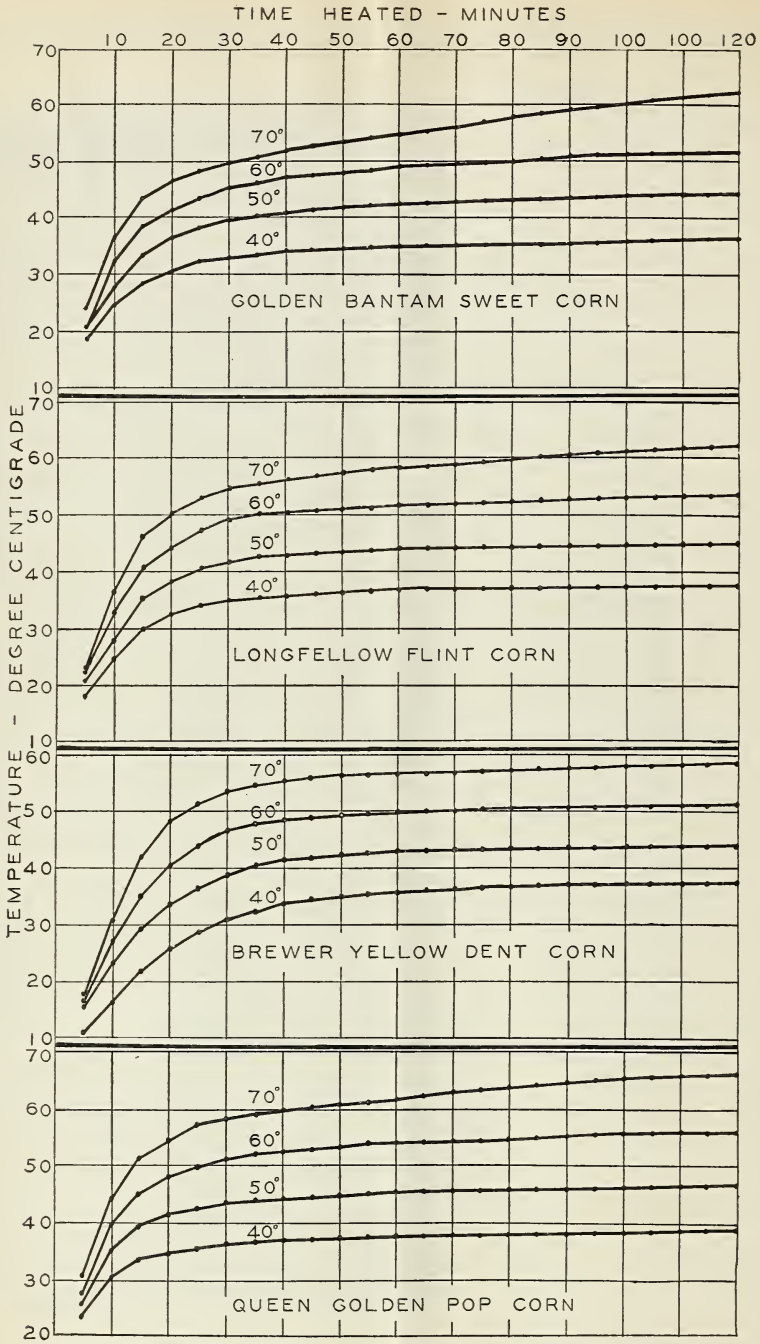

FIGURE 3.—Curves showing the rise in temperature within ears of Golden Bantam sweet, Longfellow flint, Brewer Yellow dent, and Queen Golden pop corn when subjected to constant temperatures of 40°, 50°, 60°, and 70° C. (104°, 122°, 140°, and 158° F.). Each curve is the average of 10 tests in which temperature readings were taken every 5 minutes. The number immediately above each curve shows the temperature of the container in which the ears were heated

HEATING OF INFESTED EARS

Preliminary experiments in various ways of heating infested ears of corn so as to kill the contained larvæ showed that to do this successfully in the shortest possible time it was necessary to place the ears in single layers on trays the bottoms of which were of screen wire, such as 1-inch-mesh chicken wire. When the ears were heated in mass, as in a bushel basket, a much longer time was necessary to kill the larvæ contained in the ears, the air pockets between the ears in such a container serving as barriers to the penetration of

FIGURE 4.—Larvæ of the European corn borer, 288 in number, killed by heating 1 bushel of dent corn for 2 hours at a constant temperature of 70° C. (158° F.) × 1⅓

heat. Thus, in the case of infested ears placed in the center of bushel baskets filled with ears of corn and heated at a constant temperature of 68° C. for 2, 4, 6, 8, 10, and 12 hours, the death of the larvæ contained within ears of Brewer Yellow dent corn was obtained in 12 hours and that of those in Longfellow flint corn in 10 hours, whereas 12 hours of heating failed to kill all larvæ contained in the ears of Golden Bantam sweet corn. The rise of temperature within the mass of ears was very slow, for after the ears had been heated 12 hours at 68° the temperature in the center of the mass of ears reached only 54.5°. The experiment showed that heating of ears of corn

in containers, such as baskets, would be ineffective in killing larvæ within the ears, unless the heating was for long periods.

Since the heating of ears of corn in containers such as baskets proved to be unsatisfactory for the killing of larvæ, experiments were next conducted in which the infested ears were placed in single layers in trays. Trays 2 feet wide by 3 feet long and about 3 inches deep were constructed, the bottoms being covered with 1-inch-mesh chicken wire. A frame to hold six such trays was so constructed that the trays might slide in and out, one being arranged above another with a vertical interval of 4 inches, and a free circulation of air thus allowed between the trays and among the ears to be treated. Preliminary experiments were then conducted in which small lots of infested ears of Brewer Yellow dent, Longfellow flint, and Golden Bantam sweet corn were heated at various container temperatures for several time periods to determine the temperatures and heating periods that would prove to be most practical in the destruction of the larvæ. (Fig. 4.) The container temperatures studied were from 52° to 70° C., and the time periods ranged from one-half hour to 48 hours, depending on the temperature used in any particular test.

This work was followed during the winter of 1923–24 by the heating of larger lots of infested ears at temperatures and periods of time that previous experiments had shown to be most effective in killing the larvæ. The results in this work were observed in the preliminary experiments by opening the ears of corn, noting the condition of the larvæ immediately after heating, and then placing them in vials for further observations extending over several weeks. In the later experiments in which large numbers of ears were heated, the ears of any particular type of corn used in any one test were tied together with string and hung from wires so as to protect them from mice. The ears were examined several months afterward (June, 1923, and July, 1924), the lapse of such periods allowing any larvæ that had remained alive after the heating of ears to pupate and give rise to moths. This method of handling corn following the treatment was about the same as would be accorded ear corn for seed or exhibits and permitted the natural development of any live insects within the stored ears.

The general results of all this work are given in Table 1, in which are given the percentages of larvæ killed in the several tests of heating at various temperatures and for the several periods. In this work 132 separate tests were made, Golden Bantam sweet corn being used in all. In these tests, 1,446 ears of corn were used, containing 2,946 larvæ. The tests in which Longfellow Flint corn were used were 124 in number, consisting of 1,405 ears, which contained 1,748 larvæ. In the case of Brewer Yellow dent corn, 126 tests were made, 2,145 ears, which contained 2,715 larvæ, being used. In all, therefore, 382 tests were made, a total of 4,996 ears, which contained 7,409 larvæ, being used. The infestation in sweet corn was 2.04 larvæ per ear, in flint corn 1.24 larvæ per ear, and in dent corn 1.27 larvæ per ear.

TABLE 1.—*Percentage of larvæ of the European corn borer killed by heating infested ears of various types and varieties of corn spread out on trays*

[The figures show the average of numerous tests for each period shown]

GOLDEN BANTAM (SWEET)

Container temperature (° C)	Percentage of larvæ killed during treatment lasting—									
	½ hour	1 hour	1½ hours	2 hours	2½ hours	3 hours	3½ hours	4 hours	5 hours	6 hours
70	34.62	57.89	77.32	95.11	77.08					
68	5.26	57.33	83.64	99.36	95.35					
66	21.74	38.24	75.76	84.26		91.45				
63		16.22	50.00	83.33	80.77	100.00	100.00	98.56	100.00	
60								100.00		100.00
58										10.00
52						9.09				0.00

LONGFELLOW (FLINT)

70	36.36	89.19	95.08	99.07	93.22					
68	0.00	90.00	81.81	89.34	88.44					
66	10.00	22.22	92.50	98.25	95.65	95.48				
63		25.00	20.00	96.67	85.71	96.00	100.00	100.00	90.07	
60								100.00		100.00
58										73.33
52						0.00				0.00

BREWER YELLOW (DENT)

70	11.11	60.00	76.59	99.01	83.33					
68	0.00	65.22	80.30	94.32	95.96					
66	6.67	31.68	79.55	74.51	90.58	97.99				
63		52.94	37.50	84.21	86.67	100.00	100.00	100.00	100.00	
60								100.00		100.00
58										20.00
52						0.00				0.00

GOLDEN BANTAM (SWEET)

Container temperature (° C)	Percentage of larvæ killed during treatment lasting—									
	8 hours	9 hours	12 hours	15 hours	18 hours	24 hours	30 hours	36 hours	42 hours	48 hours
70										
68										
66										
63										
60	100.00		100.00							
58		41.67	0.00	100.00	94.44	100.00				
52		14.28	20.00		20.00	67.50	50.00	88.88	91.67	100.00

LONGFELLOW (FLINT)

70										
68										
66										
63										
60	100.00		100.00							
58		100.00	81.82	100.00	100.00	100.00				
52		0.00	58.33		100.00	100.00				

BREWER YELLOW (DENT)

70										
68										
66										
63										
60	100.00		100.00							
58		50.00	30.00	100.00	100.00	100.00				
52		0.00	0.00		70.00	44.44	0.00	33.33	37.50	54.55

During the hibernating period a number of larvæ of the European corn borer die from one cause or another, the whole of such mortality being termed "winter mortality." In series of check experiments, consisting of untreated ears of corn of the several types, selected from like lots and handled in the same way as the heated ears, the average natural winter mortality in the case of sweet corn was found to be 5.19 per cent, in the case of flint corn 9.43 per cent, and in the case of dent corn 6.98 per cent of the larval population of the ears.

During the experimental work it was found that to be sure that any lot of ears was subjected to the desired degree of temperature for the full period of time, the length of the heating period should be measured from the time the heating chamber reattained that temperature after the introduction of any lot of ears. The length of time between the introduction of any lot of ears and the attainment of the desired temperature varied with the number of ears introduced and the previous temperature of the ears. When the heating period was measured in this way the results in the destruction of larvæ were the most constant and uniform although, it is true, some lots of ears were subjected to a somewhat greater accumulation of heat than was apparently necessary. The results of experiments conducted in this way are given in Table 2, and the desirability of this method of measuring the time of heating is evident when this table is compared with the average results of all the work, which are summarized in Table 1.

TABLE 2.—*Killing point of larvæ of the European corn borer determined by heating ears of corn at several constant temperatures for various periods of time*

[The beginning of the heating period was counted from the time the container reached the desired temperature after the insertion of the ears. A cross (×) indicates that all larvæ were destroyed, a cipher (0) indicates that not all the larvæ were killed]

Type of corn	Container temperature (° C.)	Destruction of larvæ during treatment lasting (in hours)—																			
		½	1	1½	2	2½	3	3½	4	5	6	8	9	10	12	15	18	24	30	36	42	48
Sweet corn	70	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	68	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	66	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	63	---	---	---	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---
	60	---	---	---	---	---	---	---	×	---	×	×	---	---	×	---	---	---	---	---	---	---
	58	---	---	---	---	---	---	---	---	---	0	---	0	---	0	×	0	×	---	---	---	---
	52	---	---	---	---	---	0	---	---	---	0	---	0	---	0	---	0	0	0	0	0	×
Flint corn	70	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	68	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	66	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	63	---	---	---	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---
	60	---	---	---	---	---	---	---	×	---	×	×	---	×	×	---	---	---	---	---	---	---
	58	---	---	---	---	---	---	---	---	---	0	---	×	---	0	×	×	×	---	---	---	---
	52	---	---	---	---	---	0	---	---	---	0	---	0	---	0	---	×	×	---	---	---	---
Dent corn	70	---	---	×	0	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	68	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	66	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	63	---	---	---	---	---	---	×	×	×	---	---	---	---	---	---	---	---	---	---	---	---
	60	---	---	---	---	---	---	---	×	---	×	×	---	×	×	---	---	---	---	---	---	---
	58	---	---	---	---	---	---	---	---	---	0	---	0	---	0	×	×	×	---	---	---	---
	52	---	---	---	---	---	0	---	---	---	0	---	0	---	---	---	0	0	0	0	0	0

Table 3 shows the period of time for which infested ears of any type of corn should be heated at various temperatures in order to

insure the killing of all larvæ of the European corn borer that may be hidden in the most protected situations in the cob.

In each case the heating period should be computed from the time the chamber attains the desired temperature after the introduction of the ears.

TABLE 3.—*Length of exposure necessary to kill larvæ of the European corn borer in ears of any type of thoroughly dried corn at various temperatures not injurious to the grain*

Constant temperature of container		Minimum exposure	Constant temperature of container		Minimum exposure
° C.	° F.	*Hours*	° C.	° F.	*Hours*
68	154.4	2½	60	140.0	8
66	150.8	3	58	136.4	24
63	145.4	5			

FACTORS INFLUENCING THE RESULTS OF THE HEATING TESTS

Certain factors that affected the results in the experimental heating may be mentioned. Ears of corn vary in several ways even within any one variety; for example, in thickness of cob, in arrangement and size of the kernels, and so on, thus providing varying degrees of insulation and consequently heating with greater or less rapidity. The location of the larvæ within the cob is such that they may be more or less protected. Thus, they may be in the very center of the ear, toward the tip of the ear, where the cob is not so thick, or toward the butt, where the cob is thickest. They may lie but little below the kernels, or in the center of the pith of the cob, or they may rest in feeding burrows among the kernels. In such a diversity of situations in the ears, varying protection is provided, and death results sooner in some of these situations than in others.

Again, the physiological condition of the larvæ varies with the time spent in hibernation, and they may be killed somewhat more easily as the time of pupation approaches in the spring. The experiments discussed in this circular could not be concluded in a day or a week. It was necessary to conduct them over a period of several months for several years, with the result that during these periods the resistance to heat by the larvæ varied somewhat. Furthermore, as shown in the experiments in which free larvæ were heated as a preliminary step in the investigations, the susceptibility of individuals to heat varies considerably at any one time.

The temperature of the ears when brought to the heating chamber from corncrib or storeroom varies with the weather and influences the rapidity with which they are heated; furthermore, the relative susceptibility of the larvæ to heat is influenced by this same factor.

Finally, relative variation in the number of ears of corn introduced into the heating chamber in any particular test influences the rapidity with which the temperature of the chamber regains the killing point after the ears are introduced. For example, if the heating chamber is heated to 68° C. the introduction of a score of ears to be treated may not result in a material lowering of the temperature, but if several bushels of ears are introduced, the temperature of the heating chamber may fall from 10 to 20 degrees and may not attain the desired temperature until as much as an hour later. This factor

was eliminated in a portion of the experimental work by measuring the duration of any heating period as beginning when the chamber had attained the desired temperature after the introduction of any lot of ears. The recommendations given in this circular are made on this basis.

It was necessary that all these factors should be taken into consideration in the preparation of recommendations for the use of heat to kill larvæ in the ears of any variety of corn. Only thus could there be assurance that the heating would kill all the larvæ contained in the ears under any given conditions.

EFFECT OF HEATING ON THE GERMINATION OF THE KERNELS AND SUBSEQUENT GROWTH OF THE PLANT

If heat is to be used to kill larvæ of the European corn borer in ears of corn, the germination of the kernels or the subsequent growth of the plant must not be adversely affected by the temperature and period of exposure required. This is particularly true in the case of seed corn that is to be shipped on the cob.

Ears of Golden Bantam sweet, Longfellow flint, Brewer Yellow dent, and Queen Golden pop corn, were selected for seed, each ear being divided into two parts and each part labeled. One-half of such an ear was saved as a check, the other half being heated along with other ears used in a certain experiment for a particular heating period at a particular temperature. Ears were heated in this way during the experiments in the winter of 1922 and again in the winter of 1923 for the time periods and the several temperatures indicated in Table 2.

In the spring of 1923 and again in the spring of 1924 sample kernels from these heated half ears, together with kernels from the check or unheated half of each ear, were tested for germination in a rag-doll tester. Plats were then planted in the experimental grounds. Each plat was planted with seed from one ear, half the plat being planted from the heated half of the ear, while the second half was planted with the check or unheated half of the ear. In this way plats planted from ears of the four types of corn previously mentioned, representing heating at various degrees of temperature for several heating periods as shown in Table 1, were planted in 1923 and 1924. These plats were subsequently examined for germination of the seed, for growth of plants, and for the production of ears. Since plants from the unheated half of any ear were grown side by side with plants from the heated half of that ear under identical conditions, the two lots of plants could be compared, and any injury to the kernels by the heating could be readily observed.

It should be emphasized in applying the results of these experiments that, owing to the fact that the moisture content of the ears used was not measured, the application of the maximum of 68° C. should be undertaken with caution. In the case of thoroughly dried ear corn the indications are that this temperature may be applied with safety as regards subsequent germination. There is considerable doubt whether such temperature could be applied without injury to corn that was not thoroughly dried.

In general it may be stated that the heated seed germinated fully as well as the check kernels, the plants were as thrifty, were of

average size, and produced as many ears as the plants from the check kernels; furthermore, no injury resulting from heating of the ears was evident except possibly in the case of certain ears heated at a temperature of 70° C. (Table 1.) Heating at this temperature has therefore been omitted from the recommendations that follow.

SUMMARY AND CONCLUSIONS

The problem of killing larvæ of the European corn borer contained in ears of corn was approached (1) by determining the temperatures necessary to kill free larvæ, that is, larvæ unprotected by the cob; (2) by determining the rapidity of the rise of temperature within ears of corn of different types and at different constant temperatures of the container; (3) by actually heating sample lots of flint, dent, sweet, and pop corn in baskets, and spread out on racks, for various periods of time at several representative constant temperatures; (4) by continuing this work with large lots of ears; and (5) by determining what effect such heating might have on the germination of the kernels, the future growth of the plants, and the production of ears. The work of determining the temperatures necessary to destroy unprotected larvæ and the rapidity of the rise of temperature within the ears of corn was preliminary, and gave approximate ranges of critical temperatures and the length of time that it might be necessary to heat infested ears to produce an effective kill of the larvæ contained in such ears. The actual heating of large lots of infested ears was the final test on which the recommendations have been based.

The more important points brought out by these studies are discussed below.

Cob and kernels offer a certain amount of insulation through which heat penetrates rather slowly, and the larvæ in burrows in the center of the cob are consequently protected from the heat for a considerable period the duration of which depends on the constant temperature used. If ears of corn are heated in boxes, baskets, or like containers, or in piles, the air pockets throughout the mass serve as further insulation, retarding the penetration of the heat. Ears should therefore be spread one layer deep on trays having 1-inch chicken-wire screening as bottoms, and these trays should be arranged on racks in the heating chamber in such a way as to allow free circulation of air about the ears.

The heating period should be measured from the time the container reaches the desired temperature after the ears have been introduced. This is necessary because the introduction of a large number of ears, particularly if taken from a crib or shed during the winter, will cause a lowering of the temperature of the container. As the desired temperature is regained slowly, the total heat absorbed may not be sufficient to produce a complete kill if the heating period is measured from the time at which the ears are inserted in the chamber.

The heating of the ears up to 68° C. for the periods of time studied was not found to affect injuriously the subsequent germination of the seed, or the growth of plants, or production of ears from such seed. The moisture content of the ears used was not determined, and for this reason the safety of such temperature may be questionable except in the case of thoroughly dried ear corn.

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